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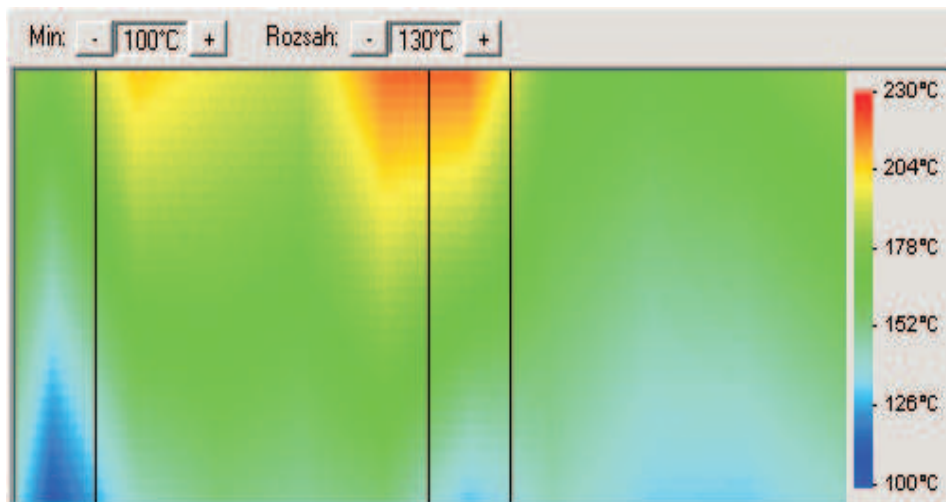


Fig. 1. Visualization of thermal field – an example of thermal field based on temperature measurement with help of thermo elements in desk of crystallizer (the anti inrush system Argus I, fa IngeTeam)

## 2. Theoretical basis of data field visualization

Before interpretation of theoretical background it is necessary to say, that some further described steps must be always chosen according to the conditions, for which the application is made.

The basis is a calculation of deviations  $e_{ij}$  between particular measured data of data field  $m_{ij}$  and presupposed (required) value or values in each points of measured field  $d_{ij}$  (where  $i$  is  $x$ -axis of the point and  $j$  is  $y$ -axis of the point)

$$e_{ij} = m_{ij} - d_{ij}. \quad (1)$$

The visualization proceeds in following steps:

Calculation of a graphic position of the measured point into the visualization model, which is defined by a scale of visualization  $mv$ , i.e. ratio of real object size and the size of the object on the monitor

$$mv = \frac{h_m}{h_{viz}}. \quad (2)$$

This scale of visualization can be the same in all measured dimensions or it is necessary to determine it in all measured directions. Further it is necessary to say, that this scale has influence on accuracy of the visualization and thus on the distinguishing level of the visualized object.

Next step is to assign a color to point in the data field. For a majority of our applications is typical, that limiting values are displayed by red color with RGB value [255,0,0] and a normalized limiting value  $\pm 1$  is assigned to them. A middle value corresponding to zero deviation is displayed by light blue color with RGB value [0,255,255]. The advantage of this way of visualization is a fast identification of boundary points; the disadvantage is then unfam-

iliarity with a limit value orientation. The applied transformation of deviations is suggested as follows:

$$\begin{aligned} e_{ij} \in \left(-1; -\frac{2}{3}\right) &\rightarrow R = 255; G = \text{trunc}(765 \cdot e_{ij} + 765); B = 0 \\ e_{ij} \in \left(-\frac{2}{3}; -\frac{1}{3}\right) &\rightarrow R = \text{trunc}(-765 \cdot e_{ij} - 255); G = 255; B = 0 \\ e_{ij} \in \left(-\frac{1}{3}; 0\right) &\rightarrow R = 0; G = 255; B = \text{trunc}(765 \cdot e_{ij} + 255) \\ e_{ij} \in \left(0; \frac{1}{3}\right) &\rightarrow R = 0; G = \text{trunc}(-765 \cdot e_{ij} + 255); B = 255 \\ e_{ij} \in \left(\frac{1}{3}; \frac{2}{3}\right) &\rightarrow R = \text{trunc}(765 \cdot e_{ij} - 255); G = 0; B = 255 \\ e_{ij} \in \left(\frac{2}{3}; 1\right) &\rightarrow R = 255; G = 0; B = \text{trunc}(-765 \cdot e_{ij} + 765). \end{aligned} \quad (3)$$

As a result we can see a colored scale illustrated on [Fig. 2].



Fig. 2. Example of normalized visualization scale

As noted previously, the visualization scale can be voted according to the concrete practical application of visualization of data fields.

The final step is the illustration of current point (deviation) on calculated coordinates of visualization model with calculated color value.

In the case of applications, when measurement contains an additional noise, for example [Fig. 3a], it is necessary to use a filter as an initial step. This filter should remove most of the noise from signal [Fig. 3b].

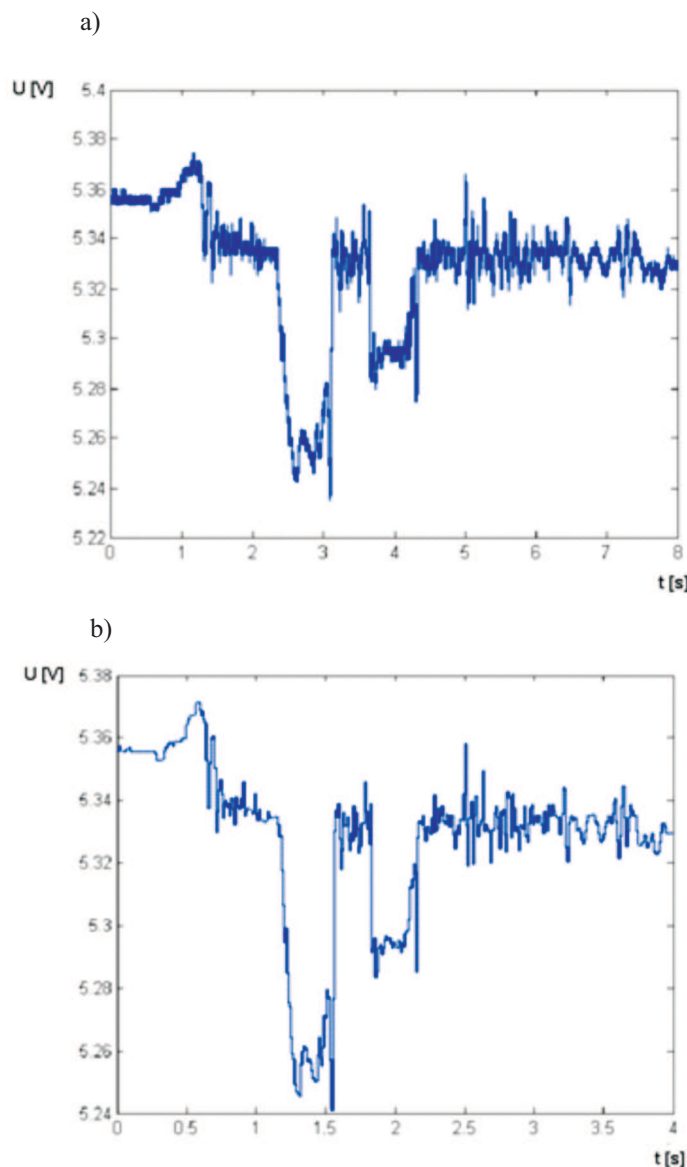


Fig. 3. (a) Data acquisition without using filter; (b) Data acquisition with using filter

It is necessary to choose a mathematical filter core according to noise signal character. For example from equations:

$$m_{ij} = \frac{\sum_{\forall \delta} m_{i+\delta, j+\delta}}{pv} \quad (4)$$

where  $\delta$  – is neighborhood of point with coordinates  $[i, j]$ ;

$pv$  – is sampling period.

Visualization between individual displayed deviations is done in several steps. The initial step is to calculate deviation between measured deviations in individual columns of data fields according to following relations:

$$\begin{aligned} e_{i,j+\xi} &= e_{i,j-1} + \left| \frac{e_{i,j-1} - e_{i,j+1}}{pb} \right| \text{ resp.} \\ e_{i,j+\xi} &= e_{i,j-1} - \left| \frac{e_{i,j-1} - e_{i,j+1}}{pb} \right| \end{aligned} \quad (5)$$

Where  $e_{i,j-1}$  a  $e_{i,j+1}$  – are measured surroundings points of point  $e_{i,j+\xi}$ ;

$pb$  – is number of points between measured, surrounding points (depends on visualization scale  $mv$ );

$\xi$  – is coordinate increment dependant on number of points between measured, surrounding points.

Further a similar calculation in rows and in outer areas of visualized object follows. The final step is to convert a determined deviation to the selected color scale according to above mentioned procedure.

In the framework of solution of problems of service life of technological devices control a software application capable a visualization of data fields were created on Department of automation and computer technology in metallurgy, VŠB-TU of Ostrava. Principle and capabilities of application will be presented on example of abrasion visualization of continual steel casting device.

### 3. VDP system (visualization of data fields)

In the working condition of continual steel casting device, inner surface state data are measured and stored by measuring system. Data are acquired in several sets in different time segments of technical crystallizer life. Within solution were created a software application capable to display abrasion on the basis on measured values. These values are gained by measuring system and they enable to acquire information on the shape of surface or abrasion of crystallizer plates.

Generated application [Fig. 4] is capable to load measured data, to calculate and display map of deviations from defined surface state, or maps expressing a taper in tracked points of crystallizer surface.

Computer program for visualization of data fields exists in several modifications at present. Two versions of this program are significant for visualization of crystallizer abrasion. The first one is determined for the visualization of tracked quantities of inner crystallizer surfaces and the second one serves for time domain analysis of changes of crystallizer during its life with possibility to predict its life time termination.

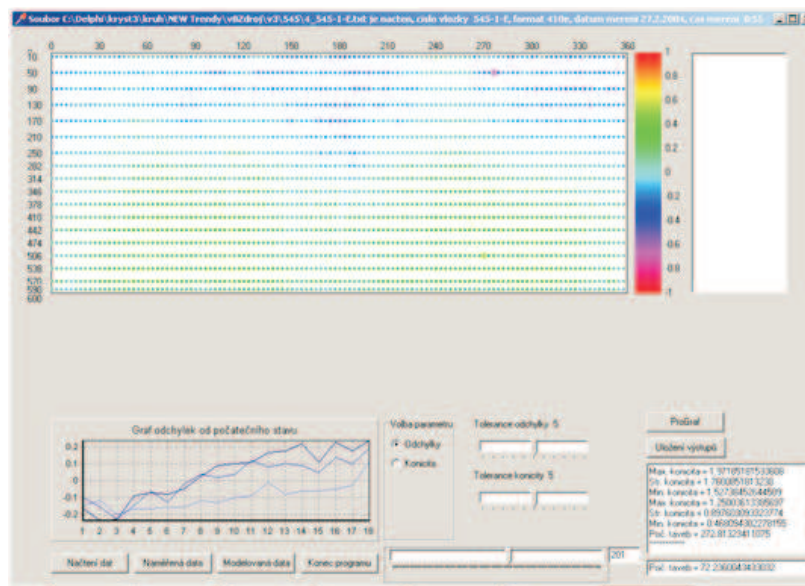


Fig. 4. General view on program screen for measurement treatment of circle crystallizer

### 3.1. Input data

Operational measurement of crystallizer surface state provides data, which are pre-processed and they are provided in a form of table, which is easily converted into text file by MS Excel® (with tabulator as column separator).

By pressing “Načtení dat” [Fig. 5] in a program environment the dialog window for file selection (source of data) will appear. The first number in file name determines measuring order. By pressing confirmation button “Otevřít”, the data are loaded and they are ready for analysis. From the file header data that are needed to identification of crystallizer

and measurement are chosen. The data are displayed in program for verification purposes.

### 3.2. Processing and visualization of loaded data

The data processing is initialized by pressing button “Naměřená data”. In the program values about geometrical size of each type of crystallizers are stored, which are utilized for calculating deviations between measured values in defined point on inner surface of crystallizer and computed theoretical values from crystallizer geometry. Deviations characterize degree of abrasion of operational crystallizer surface.



Fig. 5. Sets of control buttons

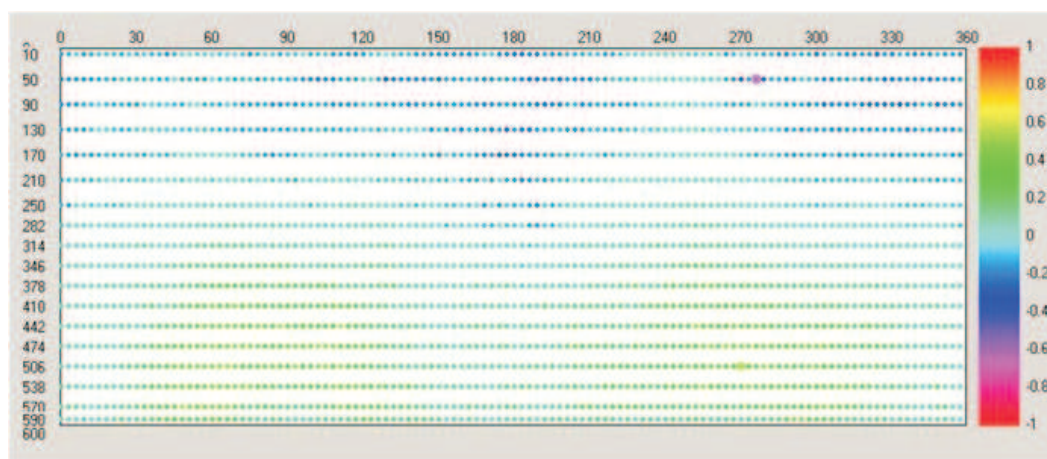


Fig. 6. Map of deviations in predefined (measuring) points



From this reason we are able to transparently display the maps of deviations in predefined (measured) points of each inner surface [Fig. 6]. The value of deviations is presented by colored shades according to color scale presented on the screen. Program enables to adjust the tolerance size of deviation by linear tension strip [Fig. 7].

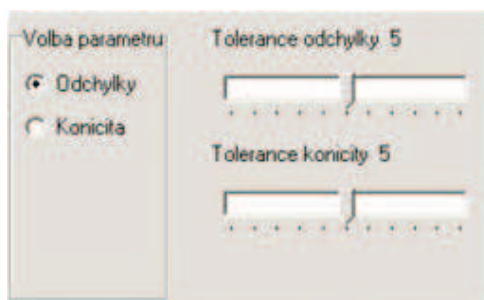


Fig. 7. Items for setting up tolerance size of deviation and taper

Points, which deviation is smaller or equal than value of set tolerance, are displayed in map by smaller colored circles. Points, which deviation is higher than value of set tolerance, are punctuated by circumscribed circle. So it is possible for the first sight detect the areas, which are outside of tolerance.

Pressing "Modelovaná data" button the program will calculate probable values of deviations using linear interpolation on the whole operational surface and project continuous map of deviations [Fig. 8].

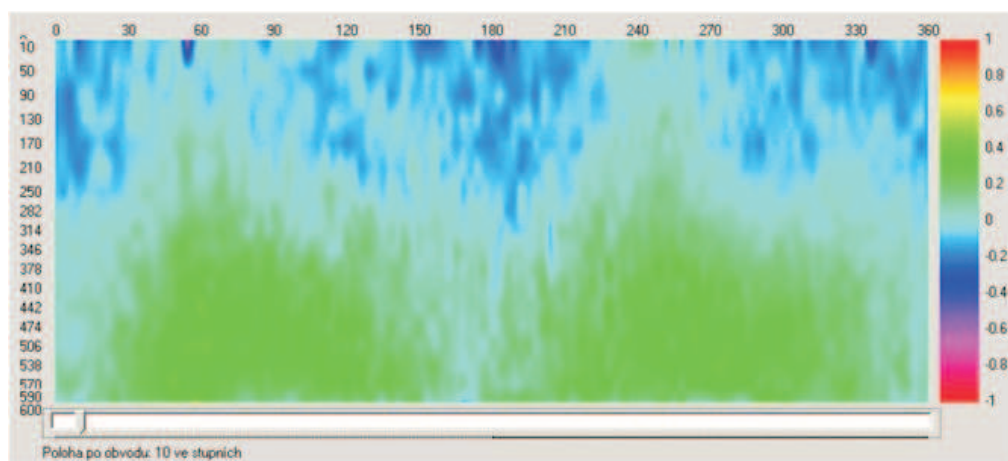


Fig. 8. Continuous map of deviations on whole inner surface of crystallizer

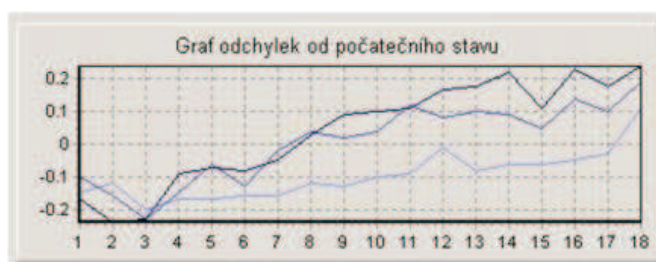


Fig. 9. Graph of deviations from initial state

This operation does not increase accuracy of visualization, but increase its lucidity (display of border points originating by extrapolation of measured values, so it is necessary to take them only as illustrative completion of map).

Visualization of the map is very useful, but real values reading by comparing colors is very subjective and inaccurate. From this reason the program has another possibility, how to find out values in one point of map selected by mouse clicking. Thus point position is obtained by coordinates dump corresponding to area size of crystallizer and value of deviation.

At the same time a graph of deviations from initial state in vertical post (longwise a crystallizer) determined by selected point is displayed [Fig. 9].

Another tracked parameter is a taper. By pressing buttons "Odchylky" and "Konicita" we can change a visualization and calculation way. These buttons are in "Volba parametru" panel. After marking request to calculate the taper, the tapers in the particular points (determined by measuring) are calculated.

Visualization of taper map of defined points is similar to visualization of deviations. Also here it is possible to determine value of taper, which can be tolerated. Clicking into the map it is also possible to obtain a numerical values or graph of tapers in vertical post along the crystallizer longitude determined by selected point.

### 3.3. Time analysis of changes on inner crystallizer surface

The second version of the program is determined for visualization and for statistical processing of measured data history. Account of that at first it is necessary to load all sets of measurements concerning only one crystallizer. After reading this data tapers relative to all longitude of crystallizer and tapers relative only to lower part of crystallizer are calculated with possibility to set level, which determine the upper border.

Thus calculated values all over the inner perimeter of crystallizer are statistically processed. Then the program displays minimum, middle and maximum value of the taper in both parts of crystallizer for particular measurement sets [Fig. 10]. Values can be stored into the text file by pressing button “Uložení výstupů” and they can be further analyzed.

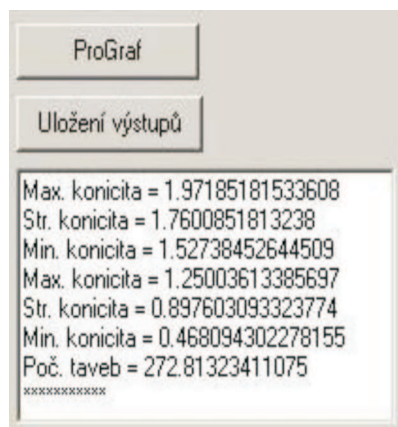


Fig. 10. Statistical values

If the result of analysis is a mathematical relation, also an estimated value of cast count or recommended value of remaining casts (to lifetime end of the crystallizer) can be displayed in the program. After pressing the button “ProGraf” the program also enables to save data accordant with the value of tapers for each measurement sets into the text file. In MS Excel® software it is possible to display data in graph and investigate dependences throughout the perimeter [Fig. 11].

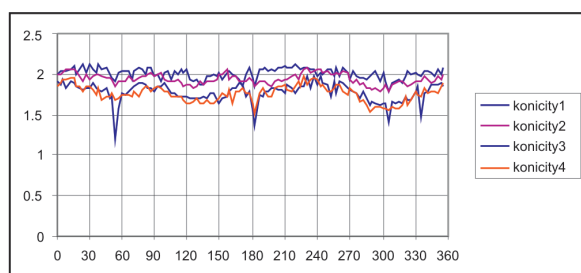


Fig. 11. Graphical dependence of tapers of each measuring sets

Program can be utilized for another data processing of purpose to analyze the state of the crystallizers during their operation.

### 4. Defects diagnostics

At present a modified version of the application is tested for surface defects diagnostics on continuously casting blanks within the project of Ministry of Industry and Trade of the Czech Republic “Development of New Progressive Tools and Systems of Dependability Control Support of Primary Cooling on Slab Device of Continuous Casting for Duality Improvement of Demanding Flat Products”. Workers from VŠB-Technical University of Ostrava and from ArcelorMittal Ostrava, a.s. participate in this project.

The aim of the project is creation of information system for support of control of dependability and crystallizer plates control under conditions of slag continuous casting of flat castings which would significantly innovate and rationalize problems of optimization of preventive maintenance of crystallizer plates applying control principle on the basic of maximal number of relevant data from technological and maintenance process. Monitoring and diagnostic-predictive systems will complete this system. They will be created by means of progressive technologies based on machine learning principles, non-destructive diagnostics, wireless identification and a number of further methods enabling failure and limiting states detection and exploitation of logistic information. Complexity of solution will complete also research of new materials of crystallizer plates which would enable expressive increase of lifetime and quality of final products.

### 5. Conclusion

The data visualization represents an important information-technological tool of future. It is given mostly by increasing possibilities of computer technology together with improving tools for visualization, manipulation and interpretation of data in real time, which represents an efficient way to discover and to understand patterns in the huge amount of data facilitating formulation of conclusions and derivation of knowledge and thus transition from the data control to the knowledge control.

The application for visualization of data fields created in Department of automation and computing in metallurgy, VŠB-TU Ostrava was presented in this paper. The application was presented on example of visualization of crystallizer wall abrasion.

The main advantage of this application is mainly the visualization of data fields for any physical quantities, the visualization of immediate state of monitored object, the presentation of historical data, the support for workers ensuring object operation, the support of identification of different states, easy modification and the user color scale setting.

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#### REFERENCES

- [1] M. Vrožina, J. David, J. M. Heger, Ověření predikce množství odlité oceli krystalizátorem. Zpráva o plnění úkolu za rok 2008 VŠB-TU-638-046-08/. Ostrava: VŠB-TU Ostrava, 2008.
- [2] M. Vrožina a kol., Využití znalostních systémů v řízení údržby metalurgických zařízení se zapojením průběžné diagnostiky do řešení. Závěrečná zpráva grantového projektu 106/05/2596 za období 2005 – 2007, VŠB-TU Ostrava, 2008.
- [3] Z. Jančíková, Exploitation of Artificial Intelligence Methods in Material Research, In Materials, Metallurgy and Interdisciplinary Co - working, 2008, Ostrava, s. 227-234, ISBN 978-80-248-1843-6.